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Behavior of Epitaxial GaN Layers on the Polyimides Polymer Substrates

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Abstract

The present work describes the succesfully growth of the epitaxial gallium nitride (GaN) layers on the polyimide polymer substrates in an Ion Beam Assisted Deposition process (IBAD), using nitrogen ions with hyperthermal energies.

The epitaxial GaN layers on the polyimide were studied *in situ* by Reflection High Energy Electron Diffraction (RHEED), *ex situ* by Scanning Electron Microscopy (SEM) and Quantum Design Physical Properties Measurement System.

The result show that the epitaxial GaN layers were grown on polyimide polimer substrate at the temperature of 150°C, and were found to be randomly distributed crystallites that have Resistivity.

High quality of GaN layers coating on polymer polyimide substrates is useful for many applications esxpecially for optoelectronic devices and semiconductors devices

Keywords: IBAD; epitaxial GaN layers; Polyimide; SEM; Resistivity .

1. Introduction

GaN layers is a promising material applications for optoelectronic devices, high-temperature operations and high-power electronic devices [1]. GaN is almost often observed as the more stable wurtzite 2H polytype (w-GaN), but can also crystallize in the metastable zinc-blende 3C structure (z-GaN) or the metastable (fcc) rock salt structure (c-GaN) [2]. Some physical and chemical technologies (e.g., molecular beam epitaxy or metal-organic chemical vapor deposition) are applied to synthesize GaN films.

Technologies based on the low-energy ion-solid surface interaction is a certain significance in many areas of thin film technology, including sputter deposition, smoothing, cleaning and etching, ion beam lithography, depth profiling and formation of nanostructures. The ability of low-energy ions (less than some keV) to affect the nucleation of thin films/layers, crystallinity, morphology, and defect concentration, as well as the surface topography, can provide significant modification of properties of the thin film/layers [1]. In correlation with conventional deposition techniques, low-energy ions can use the modify the structure of layer and its composition.

Ion beam assisted deposition (IBAD) refers to who uses energetic ions to change the properties of thin film and/or modify its structure during the deposition. Ion energy and flux, as well as the arrival rate of ions to deposited atoms (ion to atom ratio, I/A) are important parameters for controlling the structure and properties of the thin film. In almost all experiments and ion beam technologies to fabricate thin films, ions with energy between 1 keV and 10 keV were utilized, although it is known that increase of the ion energy leads to a significant increase in the concentration of defect in the growing film. Consequently, modern trend are to using called hyperthermal ions with kinetic energy smaller than 100 eV to modify the behaviour of thin films [3,4]. Hyperthermal ion assistance during epitaxial growth can lead to GaN thin films of high quality [5].

In this paper, we report the growth of epitaxial gallium nitride (GaN) layers on polymer polyimide substrates via Ion Beam Assisted Deposition process (IBAD) using nitrogen ions with hyperthermal energies. The Reflection High-Energy Electron Diffraction (RHEED), Scanning Electron Microscopy (SEM), and Quantum Design Physical Properties Measurement System were conducted to investigate the behaviour of the epitaxial GaN layers on the polymer polyimidis substrates.

2. Materials and Methods

The epitaxial GaN layers were grown on polyimide polymer substrates by ion beam assisted deposition (IBAD) process that is interconnected with ultra-high vacuum chambers for the film deposition including reflection of high-energy electron diffraction (RHEED) for in situ studies of film growth. Ion beam assisted deposition of GaN in the same polymide in principle Ion Beam Assisted Molecular Beam Epitaxy (IBA-MBE) process described in previous works [3, 6]. The only variations is the amorphous character of the polyimides, which leads to a non-epitaxial growth. The residual gas pressure prior deposition was 10^{-8} Pa. Ga was deposited by an effusion cell at temperatures between 950 °C and 1050 °C. In this temperature range the deposition rate ΦGa varied between 5×10^{13} and 2×10^{14} Ga atoms/cm² according to the calibration relation $\Phi Ga = 8 \times 10^{7} \times \exp(TEC/71)$ obtained by Rutherford backscattering spectroscopy (TEC is the temperature of the effusion cell). . The energy of these hyperthermal ions between 20 eV until 50 eV, and the nitrogen ion flux of 1.6×10^{14} ions/cm² was kept constant.

The thin film deposition process was monitored in situ by reflection high energy electron diffraction (RHEED). The surface topography of the grown layers of GaN was investigated *ex situ* with Scanning Electron Microscopy (SEM). The images were collected by the SE analysis with an *FEI Quanta 250* microscope with Everhart-Thornley detector (EDT) and a *Zeiss AURIGA* with a lens detector. The resistivity of the GaN layers on polyimides substrate was investigated *ex situ* with the Quantum Design Physical Properties Measurement System EverCool-II™ at room temperature.

3. Results and Discussion

We were studying high-quality growth of epitaxial GaN layers on polyimide polymer substrates. The principle for the progress of semiconductor devices in the polymers is a knowledge of the growth mechanisms that occur especially in the initial stages of film formation.

In this study, the epitaxial GaN layers were grown on a polyimide polymer substrates by the Ion Beam Assisted Deposition (IBAD) process using nitrogen ions with hyperthermal energies. The epitaxial GaN layers on the polymer substrates were analyzed by various methods *in situ* and *ex situ*. This experiment originally described the method of analysis, starting with *in situ* RHEED measurements, followed ex situ by surface topography characterization with SEM, and resistivity measurement with Quantum Design Physical Properties

The resulting RHEED pattern is mostly originating from the elastically scattered electrons. **Figure 1** shown the formation of a polycrystalline ring pattern of GaN on polyimides substrate during deposition. Since the GaN is grown polycrystalline, the expected ring pattern shows up, where every ring is the diffraction pattern of one family of lattice planes. In case of random orientation of the crystallites, the pattern consists of complete rings, while for a film with preferred orientations broken rings are observed. As shown in **Figure 1** c) and d), this break up happens in the later stages of growth, while for 60 min deposition time still complete rings can be observed.

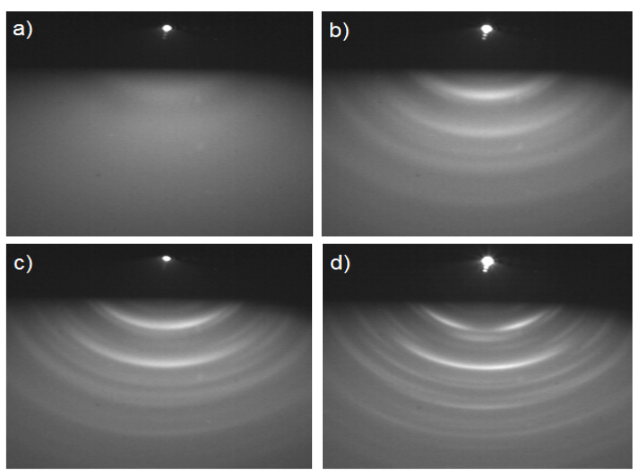
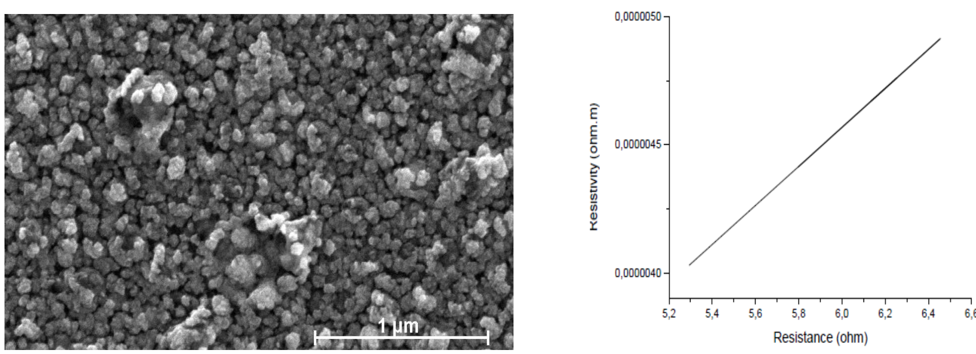


Figure 1. RHEED pattern of GaN layers grown on polyimide Kapton polimer substrate at a) the beginning of the deposition, b) after 30 minutes, c) after 60 minutes and d) after 120 minutes of deposition time (end of the process).

The surface topography of the grown epitaxial GaN layers on the polyimides polymer substrate was investigated *ex situ* with SEM to obtain a qualitative impression of the layer quality and surface roughness stacks and randomly distributed crystallites are formed from the small gallium droplets, with voids in between and smaller crystallites on top. A detailed view on the rough surface of GaN layers on the polyimides polymer substrate deposited at 150°C, is shown in **Figure 2a.**

From resistivity measurement used Quantum Design Physical Properties Measurement System EverCool-II™ at the room temperature (see in **Figure 2b**). We found the Resistance of epitaxial GaN layers on the polymer polyimides subtrates around 5.0 – 7.0 ohm.



(a) (b)

Figure 2. Deposition epitaxial GaN thin films on polyimide Kapton polimer substrate at 150°C (a) SEM image of the rough surface with randomly distributed crystallites,
b). Curve Resistivity (ohm.m) Vs Resistance (ohm)

Wurtzite nanocrystallite epitaxial GaN layers was successfully grown on the polymer polyimide substrates via IBAD process using nitrogen ions with hyperthermal energies. The optimum conditions for epitaxial growth and high quality of GaN layers on the polyimide substrates is sufficient to create semiconductor devices. Furthermore, some practical purposes and application still need to be done in the future studies.

Acknowledgements

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